AMERICA'S NOBEL LAUREATES

IN MEDICINE, PHYSIOLOGY AND CHEMISTRY

In celebration of the Sesquicentennial of the National Library of Medicine — second edition

AMERICA'S NOBEL LAUREATES IN MEDICINE, PHYSIOLOGY AND CHEMISTRY

"A Tribute to America's Living Nobel Prize Winners"
By Larry Thompson

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INTRODUCTION

In 1986, the National Library of Medicine celebrated the 150th anniversary of its founding. As part of the Sesquicentennial activities, a Tribute Dinner was held to honor America's living Nobel laureates in medicine, physiology, and chemistry, and a journal was published documenting their contributions.

Given the strong interest the first edition of the Nobel Laureate Journal generated, the Friends of the NLM, the National Center for Health Education, and the National Library of Medicine decided to publish an updated version. Time constraints prevented the first edition from including the biographies of the Nobel laureates who were not able to attend the Tribute Dinner. This edition is intended to be a comprehensive survey of America's living Nobel laureates in medicine, physiology, and chemistry.

It is hoped that this publication will provide a useful overview of these Americans' great scientific accomplishments. In addition, we hope the vital link between great breakthroughs in science and access to the world's best medical information is clearly documented.

THE FRIENDS OF THE NATIONAL LIBRARY OF MEDICINE

THE NATIONAL LIBRARY OF MEDICINE: THE WORLD'S LINK TO HEALTH

From a few shelves of books to the world's largest medical library — this is the amazing story of the National Library of Medicine (NLM). In 1836, when those first shelves were officially designated as the Library of the Army Surgeon General's Office, no one would have imagined that over 150 years later this tiny nucleus would have grown to more than 3.5 million books and thousands of journals, reports, and pictures — all available to the world's dedicated physicians and scientists, who use this information to help everyone attain the birthright of good health.

It was just such a dedicated physician who made the National Library of Medicine the treasure it is today. Dr. John Shaw Billings, a Civil War surgeon, was the guiding spirit who put the library on its path to greatness by becoming its director in 1865. Its growth began almost immediately and, in 1866, he found more space for the collection in Ford's Theatre in Washington, the site of Lincoln's assassination.

Medical and scientific knowledge was burgeoning at the time, and Billings was devoted to acquiring all that was significant in the healing arts. As a result, the collection grew with great speed. It was the dawn of a new scientific age in medicine, and researchers were making discoveries constantly. Reports of their findings were arriving daily at the library, where they were not only cataloged and shelved, but shared with anyone who was interested — a tradition that is more alive today than ever.

Expanding so quickly, the library soon outgrew its cramped quarters in the theatre. With great foresight, Billings had been active not only as a librarian, but also as a persuasive spokesman for medical information services. Through skillful presentations, he was able to convince the Congress and the President that the library must grow to fulfill its mission as the nation's principal source of medical knowledge.

As a result of his efforts, the library moved in 1887 into its own headquarters on the mall in downtown Washington. Under his guidance, its collection and influence grew dramatically, and its international reputation as the world's most comprehensive collection of medical information began to build. Billings's thirty-year stewardship of the library has left a lasting monument, not just in bricks and mortar or books and paper, but in the ever-growing improvement in the nation's health.

After Billings, the library continued to expand its holdings and services. In 1956, an Act of Congress transferred the governance of the collection from the Department of Defense to the Department of Health, Education and Welfare (now the Department of Health and Human Services). At the same time it gave the collection (by then known as the Armed Forces Medical Library) a new name reflecting its scope: the National Library of Medicine.

Keeping pace with the enormous flow of new medical information, the library in 1962 once again moved into a new and much larger building, this time on the National Institutes of Health campus in Bethesda, Maryland. In 1968 it formally became part of NIH. Finally, to accommodate the latest computer equipment for information storage and retrieval, a second building, the Lister Hill Center, was opened in Bethesda in 1980.

The National Library of Medicine Today

Today, with materials in seventy languages and the capability to exchange information internationally, the National Library of Medicine is a worldwide link among all health professionals. In the United States, NLM is the hub of the national network of 7 regional medical libraries, 125 resource libraries at medical schools and 4,000 local medical libraries placed strategically in every area of the country. Most physicians and scientists are only minutes away from one of these network libraries, permitting ready access to the riches of the world's medical literature.

The computer revolution is bringing that literature even closer to the nation's practicing physicians. From their own offices, doctors can use MEDLINE, NLM's computer database of over five million references to journal articles. Searches that used to take days are completed in minutes. MEDLINE, growing at a rate of 300,000 entries a year, allows individuals not only to call up a list of pertinent articles, but also to print abstracts for many of those articles at their own terminals. Already MEDLINE is available at 5,000 institutions, including universities, medical schools, hospitals, government agencies, and businesses. Now more and more individual health professionals are discovering that using MEDLINE in their offices gives them immediate access to the vital information they need to fight their patients' illnesses and bring them back more quickly to healthy, productive lives. Every day more health professionals are finding MEDLINE and NLM to be indispensable to their practice.

In the Future at the National Library of Medicine

The future of medical communication and education is taking shape now at the National Library of Medicine. Specifically, NLM's Lister Hill National Center for Biomedical Communications is at the forefront of applications of the latest technology to the ancient art of medicine.

The center played a lead role in developing MEDLINE in the late sixties, and since then it has conducted a number of valuable communications experiments using NASA satellites, microwave and cable television, and computer-assisted instruction.

Currently the Lister Hill Center is investigating the exciting potential of microcomputer, optical videodisc, and voice-recognition technologies to develop truly interactive medical education programs. In addition, artificial intelligence techniques are being applied to the development of "expert systems" that will assist health practitioners in treating systems.

The National Library of Medicine: Communication is the Goal

From a few books on a shelf to the most sophisticated computer technology, NLM's story is one of amazing growth and development. Throughout its history, however, its goal has remained the same: to be

ready to communicate as quickly as possible all the biomedical information available wherever it is needed.

As the National Library of Medicine begins the next 150 years, we look forward to communication breakthroughs that are now almost impossible to imagine. And, it is a certainty that the NLM will continue in the vanguard of the information revolution.

THE NOBEL PRIZES, 1901-1986

It may seem ironic that Alfred Bernhard Nobel, a chemist and industrialist specializing in the production of explosives and inventions of warfare, established a prize to be awarded to those who "conferred the greatest benefit on mankind."

Yet to those who knew him well, this was not surprising. Even while experimenting with the most powerful explosives, his ambition was to insure their safe use. Nobel devoted years to discovering a way to use the explosive power of nitroglycerin in a safer and more stable form. Perhaps his dedication derived partly from the tragic loss of his brother in an explosion at their father's research laboratory. Whatever the reason, Alfred Nobel left an enduring legacy the world will always value.

Today, the Nobel Prize is the most prestigious and coveted award in the world. The elaborate process for selecting its laureates, as described in Nobel's will, along with its history of outstanding recipients in all categories, has established the Nobel Prize as the highest international award.

Nobel was born in Stockholm in 1833. In 1842, his father, also a technician and inventor, moved his family to St. Petersburg, where he manufactured submarine mines and torpedoes, of his own design, for the Russian government. As a young man, Alfred became active in his father's business and traveled widely in Europe and America.

Returning to Sweden in 1859, he experimented with the production of nitroglycerin in his father's laboratory. It was there in 1866 that he invented dynamite, an explosive made of nitroglycerin absorbed in a porous material. Thus, for the first time, the explosive power of nitroglycerin was available in a stable form.

He formed a company and established plants and offices around the world, making it one of the early multinational corporations.

After he died in 1896, most of his fortune, valued then at $8,311,000, went to establish a fund for the Nobel Prizes. Interest from the fund was to be distributed annually "in the form of prizes to those who have . . . conferred the greatest benefit on mankind." Further, the interest was to be divided into five equal portions to be awarded to persons who had made the most important contributions in physics, chemistry, medicine or physiology, and literature, and to the one who had done the most or the best work for fostering fraternity among nations, for the abolition of standing armies, and for the holding and promotion of peace conferences.

Nobel stipulated that the prizes for physics and chemistry be awarded by the Swedish Academy of Sciences, for physiology or medicine by the Karolinska Institute in Stockholm, for literature by the Swedish Academy, and for peace by a five-member committee, elected by the Norwegian Storting (Parliament). No consideration was to be given to the nationality of the candidates. The first prizes were awarded in 1901.

In 1968, the Riksbank, the central bank of Sweden, created the Nobel Prize in economics to commemorate the bank's 300th anniversary. The bank provides the same amount of money allotted for the other prizes, and the Swedish Royal Academy of Science selects the winner(s).

All the prizes are presented on December 10th, the annversary of Nobel's death, in Stockholm, except for the peace prize, which is given in Oslo. The cash prize is accompanied by a diploma and a gold medal, and each laureate gives a lecture on the work for which the prize was awarded. These lectures are published annually by the Nobel Foundation in ***Les Prix Nobel.***

AMERICA'S NOBEL LAUREATES

IN MEDICINE, PHYSIOLOGY AND CHEMISTRY

William P. Murphy 1934 Physiology or Medicine

Although it still kills, pernicious anemia no longer captures the public mind as does cancer or acquired immune deficiency syndrome (AIDS). Yet, since it was first described in 1849, pernicious anemia was a mysterious and lethal disease.

With the help of the late Dr. George R. Minot, with whom he shared the Nobel Prize, Dr. Murphy helped introduce "the era of liver therapy," in which liver extracts were injected into the muscle of patients with pernicious anemia in an effort to restore normal red blood cell levels.

Although the treatment worked dramatically well — "We have been allowed the thrill of watching the patient through a few days of depression following the institution of liver therapy until remission occurs with its often sudden and almost unbelievable sense of well-being simultaneously with the maximum increase of the reticulocytes or new red blood cells," Dr. Murphy said in his Nobel address — there still were problems. "The problem . . . has been the practical one of making treatment more bearable for the victim of pernicious anemia, who must necessarily continue treatment indefinitely in order to maintain a satisfactory state of health." Even then, there were issues of efficiency and cost control.

Dr. Murphy concluded his remarkably short Nobel lecture with "a motion picture which will illustrate many points more clearly than I could discuss them here." In 1934, that must have been a dazzling display.

Born in Stoughton, Wisconsin, in 1892, Dr. Murphy received his A.B. from the University of Oregon in 1914 and his M.D. from Harvard Medical School in 1920. He remained affiliated with Harvard's Peter Bent Brigham Hospital for most of his professional life, retiring as emeritus professor in 1958.

Glenn T. Seaborg 1951 Chemistry

Every introductory chemistry classroom in America has a periodic table of the elements on a wall somewhere, it is chemistry's touchstone. The table's bottom row contains elements that do not occur in nature — the so-called transuranium elements.

These elements are man-made, created in the blinding, high-energy collisions of uranium, plutonium, and other heavy nuclei with accelerated particles, the ions of low atomic number elements such as carbon, nitrogen, and oxygen, among others.

Dr. Seaborg, working with Dr. Edward O. Lawrence and others at the accelerators on the hill behind the University of California at Berkeley campus, played a role in creating 10 and naming 9 of the 13 transuranium elements, those carrying the atomic numbers 94 to 102 — including plutonium (94), americium (95), curium (96), berkelium (97), californium (98), einsteinium (99), fermium (100), mendelevium (101), nobelium (102), and element 106.

Born in Ishpeming, Michigan, in 1912, Dr. Seaborg received his A.B. in chemistry from the University of California at Los Angeles in 1934. He received his Ph.D. in chemistry in 1937 from the University of California at Berkeley, where he has served as a faculty member since that time. Rising through the academic ranks at Berkeley, he served as Chancellor from 1958 to 1961. Twice Dr. Seaborg received a leave of absence from California: once during World War II when he was in charge of plutonium chemistry for the Manhattan Project at the University of Chicago's Metallurgical Laboratory, and again when he served as chairman of the Atomic Energy Commission (appointed by Presidents Kennedy, Johnson, and Nixon) from 1961 to 1971. He continues his work at the University of California as university professor of chemistry, as associate director of the Lawrence Berkeley Laboratory, and as chairman of the Lawrence Hall of Science.

Linus C. Pauling 1954 Chemistry 1962 Peace

Linus C. Pauling was born in Portland, Oregon, in 1901. He received his bachelor's degree in 1922 from Oregon State College and his Ph.D. degree in chemistry in 1925 from the California Institute of Technology.

Dr. Pauling is the only man to win two Nobel Prizes in different categories: He was awarded the Nobel Prize in Chemistry for 1954 and the Nobel Peace Prize for 1962.

Dr. Pauling has always been a man of science. He spent most of his professional life studying the nature of the chemical bonds that hold atoms together.

His experimental work included x-ray diffraction of crystallized proteins to study their structure, insights into the molecular basis of general anesthesia, and the role of abnormal molecules in causing disease—such as the deformed hemoglobin molecule in sickle cell anemia. His chemical studies included an extension of the valence theory of atomic bonds to include metals and intermetallic compounds, theoretical work on the structure of atomic nuclei and insights into the process of nuclear fission.

Dr. Pauling has received many other awards in the fields of chemistry, mineralogy, biology, medicine, and peace. He has published over 600 scientific papers, about 200 articles on social and political questions, and many books, one of which ***(The Nature of the Chemical Bond)*** is one of the most cited scientific books of the twentieth century. He is the founder of and a research professor at the Linus Pauling Institute of Science and Medicine in Palo Alto, California.

Frederick C. Robbins 1954 Physiology or Medicine

The collaboration between Dr. Robbins and his co-laureates, Drs. John F. Enders and Thomas H. Weller, proved to be an unusually productive one. In January 1948, following completion of his pediatric training, Dr. Robbins joined the Research Division of Infectious Diseases that had been established by Dr. Enders about a year previously at Boston's Children's Hospital. Dr. Weller, a medical school classmate and former roommate, was already in the laboratory. A major interest of the group was the growth of viruses in tissue culture.

Although poliomyelitis was originally not their principal interest, they did conduct experiments with poliovirus and discovered that it could be grown in cultures of nonnervous cells. They then developed methods for assaying the growth of the virus in culture. These findings made it possible to develop vaccines and to use tissue culture methods as substitutes for animals. This latter finding was particularly important as up until this time the only universally susceptible experimental animal had been monkeys. The techniques they developed for studying poliovirus proved to be useful in the study of a variety of other viral diseases (e.g., measles, German measles, and mumps), and the development of vaccines for their control.

The growth of the poliovirus in nonnervous tissue helped to establish, contrary to the belief of some, that poliomyelitis was primarily an infection of the intestinal tract, with only an occasional invasion of the bloodstream and secondary infection of the nervous system.

Born in Auburn, Alabama, in 1916, Dr. Robbins received a B.A. in 1936 and an M.S. in 1938 from the University of Missouri, at Columbia. In 1940, he received his M.D. from Harvard University. He then served four years in the U.S. Army in charge of a virus and rickettsial diseases laboratory. For two years he was stationed in Italy, where he supervised a study that established that the rickettsia of Q Fever was the cause of epidemics of febrile disease and pneumonia in American troops in Italy. This was the first time Q Fever had been recognized in this part of the world. After his military service, Dr. Robbins worked at Children's Hospital in Boston and at Harvard University before finally settling in 1952 at Case Western Reserve University School of Medicine as a professor of pediatrics and the director of the Department of Pediatrics and Contagious Diseases at the Cleveland City Hospital (now Metropolitan General Hospital). He also served as dean of the School of Medicine at Case Western Reserve from 1966 through 1980 and as president of the Institute of Medicine of the National Academy of Sciences from 1980 through 1985. Dr. Robbins is now university professor emeritus and dean emeritus of the School of Medicine at Case Western Reserve University.

Dr. Thomas H. Weller 1954 Physiology or Medicine

Polio had been a terrible scourge. Pools closed; parents kept their children out of crowds. Then the cause, a threesome of closely related viruses, was discovered. Dr. Weller and his colleagues, Drs. John Enders and Frederick Robbins, successfully cultivated the polio virus when they learned to "substitute the test tube for the monkey." That allowed them, for the first time, to grow large amounts of the virus in tissue cultures. This breakthrough helped lead to the development of a successful polio vaccine.

In addition to working on polio, Dr. Weller developed ways to grow other viruses in tissue cultures. These techniques led to the isolation of important new viruses, including rubella, which causes German measles and the varicella-zoster virus, which causes chicken pox and shingles.

As a pediatrician specializing in infectious diseases, Dr. Weller also showed that viral infections can be transmitted from a pregnant mother to her fetus. An important example of new agents he isolated and named are the cytomegaloviruses. He showed that these new viruses, such as the rubella virus, are important causes of intrauterine fetal damage.

As director of the Center for the Prevention of Infectious Diseases at the Harvard School of Public Health from 1966 to 1981, Dr. Weller carried out important studies on ***Schistosoma mansoni***, the cause of schistosomiasis, a serious and widespread tropical parasitic disease.

Born in 1915, Dr. Weller received his B.S. in 1936 from the University of Michigan (where his father was professor of pathology) and his M.S. in 1937; he received his M.D. from Harvard in 1940. Except for his service in the Army Medical Corps from 1942 to 1945 (where he rose from first lieutenant to major), Dr. Weller has been with Harvard throughout his career. Previously Richard Pearson Strong Professor of Tropical Public Health he was named professor emeritus in 1985.

George W. Beadle 1958 Physiology or Medicine

His tools were classic: fruit flies, the red bread mold *Neurospora crassa*, and maize. With them, he helped lay the foundation for the field of chemical genetics by showing convincingly that each individual gene produces one specific protein — though the theory initially was described as "one gene-one enzyme."

Dr. Beadle and his partner Edward L. Tatum, both then at Stanford University, made mutants of *Neurospora* with radiation — which was known to change the gene's DNA — and grew the altered mold in a richly supplemented growth media. They then searched for mutants that could not survive without supplemented media and quickly found dozens, including mutant 299, which required vitamin B6 to grow, and mutant 1085, which required thiamine-vitamin B1. The mutants arose because the radiation changed a single gene that produced an individual enzyme that performed some essential function needed for survival, such as the synthesis or processing of vitamins.

The work was further refined as it became clear that some proteins have more than one unique string of amino acids, or a polypeptide. Some proteins, such as hemoglobin, contain two different polypeptide chains to make the mature protein, with two genes encoding the directions for the different polypeptides.

Born in Wahoo, Nebraska, in 1903, Dr. Beadle received his B.S. in 1926 and his M.S. in 1927 from the University of Nebraska. Cornell University awarded him a Ph.D. in 1931. Altogether, he spent 20 years at the California Institute of Technology during two different stays, and 9 years at Stanford University and several other institutions before settling at the University of Chicago in 1961, where he was president of the university until 1968. Dr. Beadle now lives in Pomona, California.

Joshua Lederberg 1958 Physiology or Medicine

For the past 40 years, bacteria have provided the model system for study in molecular genetics. In 1946, Dr. Lederberg discovered that a form of sexual reproduction occurs in these microorganisms, demonstrating that they possess a genetic mechanism similar to that of humans. Combine this with their simple structure and rapid growth cycles, and one has a superb system on which to base a study of genetic development.

Dr. Lederberg was born in Montclair, New Jersey, in 1925. He earned his Bachelor's degree at Columbia University, and attended its College of Physicians and Surgeons for two years, but then took sabbatical leave to work at Yale with Dr. Edward J. Tatum, a pioneer in bacterial genetics. Never returning to medical school, he received his Ph.D. from Yale in 1947. Dr. Lederberg was professor of genetics at the University of Wisconsin from 1947 to 1959. In 1952, he and Norton Zinder demonstrated that bacterial genetic information is also passed when bits of chromosomic material are incorporated into viruses that infect other bacterial cells. Other studies revealed a number of other genetic particles in bacteria that have become instrumental in recombinant DNA research, and substantiated how to think about bacteria in genetic terms.

He received the Nobel Prize for this work in 1958, along with Dr. Tatum and Dr. George Beadle.

In 1959, Dr. Lederberg moved to Stanford University Medical School, where he became chairman of the Department of Genetics. At Stanford, he collaborated with E. A. Feigenbaum in artificial intelligence, pioneering the development of "expert systems." In 1978, he was appointed to the presidency of the Rockefeller University, the post he holds today.

Dr. Lederberg was active in planning the Mariner and Viking missions to Mars, and has served as a consultant to the Arms Control Disarmament Agency and to the World Health Organization. In addition, he has written a weekly syndicated column for The Washington Post on the social impact of scientific progress. Dr. Lederberg is science's answer to the oft-repeated criticism that scientists have narrow interests.

Arthur Kornberg 1959 Physiology or Medicine

In 1953, the fundamental structure of deoxyribonucleic acid (DNA) was described for the first time, but its twisted ladder shape told little about how it directed the production of proteins or how it was faithfully reproduced to pass genetic instructions from one cellular generation to the next.

Dr. Kornberg worked on the latter problem, and discovered the synthetic pathways by which the activated subunits of DNA — the four types of nucleic acid, or nucleotides — are produced. His work also led to the discovery of some of the enzymes that unzip the two halves of the DNA ladder and then align activated nucleotides along each half in a complementary way. This enzyme-controlled aligning produces two identical copies of the original piece of DNA.

Although his main research continues to focus on biochemical questions, Dr. Kornberg also has worked on reactions in the Krebs cycle that converts food into a form of stored energy that can be used in chemical reactions and phospholipid synthesis.

Born in Brooklyn, New York, in 1918, Dr. Kornberg received his B.S. from the City College of New York in 1937 and his M.D. from the University of Rochester in 1941. The following year, he moved to the National Institutes of Health and began studying rat nutrition. In 1946, he studied enzymology with Dr. Severo Ochoa, with whom he shared the Nobel Prize.

In 1953, Dr. Kornberg moved to Washington University School of Medicine in St. Louis as chairman of the Department of Microbiology, to begin the work for which he is best known. In 1959, he became professor and chairman of the Department of Biochemistry at Stanford University.

Severo Ochoa 1959 Physiology or Medicine

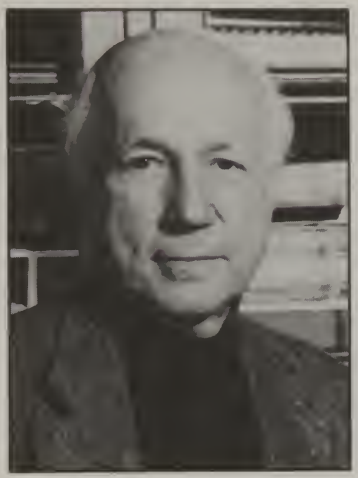
Enzymes are the key to all biological actions, to the chemistry of life itself. Dr. Ochoa spent much of his research career working on enzymatic mechanisms, providing insights into biological oxidation, synthesis and energy transfer, and contributing to the understanding of the basic steps in carbohydrate and fatty acid metabolism, carbon dioxide utilization and nucleic acid biosynthesis.

Dr. Ochoa received his Nobel for purifying in 1955 and working out the chemistry of polynucleotide phosphorlase, an enzyme that can produce chains of RNA without the need of a DNA template. The enzyme proved critical in working out, in the beginning of the 1960's, how DNA carried the instructions of heredity. His familiarity with this enzyme made Dr. Ochoa a key competitior in the race to decipher the genetic code, a race ultimately won by Nobel laureate Dr. Marshall Nirenberg.

Other work by Dr. Ochoa included research into the function of vitamin B1 oxidative phosphorylation, reductive carboxylation of ketoglutaric and pyruvic acid, photochemical reduction of pyridine nucleotides in photosynthesis, and condensing enzyme, a key enzyme in the Krebs citric acid cycle.

Born in Luarca, Spain, in 1905, Dr. Ochoa received his B.S. from Malaga College in 1921. He received his M.D. from the University of Madrid Medical School in 1929. He spent much of his formative years under the influence and guidance of other Nobel winners, including Dr. Santiago Ramon y Cajal and Dr. Otto Meyerhoff. He had an international scientific career, including stops at the Kaiser Wilhelm Institut für Biologie in Berlin-Dahlem: the National Institute for Medical Research in Hampstead London: Oxford University: and the University of Madrid. He came to the United States in 1940, working first at the Washington University School of Medicine in St. Louis — with Drs. Carl and Gery Cori, who also won a Nobel prize —and then at New York University College of Medicine in 1942. He became an American citizen in 1956. Dr. Ochoa now lives in Madrid.

Melvin Calvin 1961 Chemistry

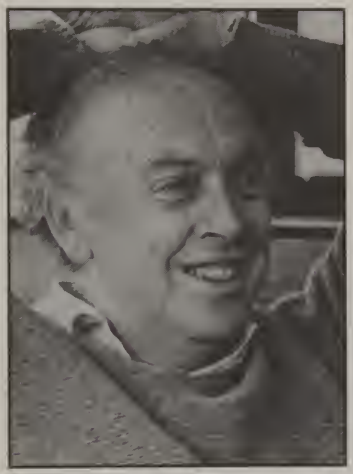


The quiet green of a forest glen belies the frenetic activity within every leaf as they use the energy of sunlight to drive a cascade of chemical reactions that — adding together the activity of all the plants in the world each year — convert an estimated 150 billion tons of carbon from carbon dioxide in the air and about 25 billion tons of hydrogen from water into 400 billion tons of oxygen and enough energy to maintain animal life and provide the fossil fuels that propel nearly every human enterprise.

This process of photosynthesis is believed to be at least 30 percent efficient and, in some circumstances, approaching 100 percent efficient. But the chemistry involved is hideously complicated. From 1845, when it was first discovered, until the 1930s, all scientists knew about photosynthesis was that carbon dioxide and water went in and oxygen came out. Dr. Calvin, however, using radioactive elements to label and trace organic molecules, began to unravel the process. In the 1940s, when radioactive carbon became available, he finally was able to decipher the central, critical steps and show that when sunlight strikes chlorophyll, the plant's green pigment splits water into hydrogen and oxygen; hydrogen enters into synthetic reactions with carbon that lead to energy being stored in the form of sugar; oxygen, in this case, is a waste product. The identification of the various pathways in the photosynthetic carbon reduction cycle took approximately eleven years, from 1947 to 1958.

Born in St. Paul, Minnesota, in 1911, Dr. Calvin received his B.S. in chemistry from Michigan College of Mining & Technology. He received his Ph.D. in chemistry from the University of Minnesota in 1935. After postdoctoral work at the University of Manchester in England, Dr. Calvin began his teaching and research career in the departments of Chemistry and Molecular Biology at the University of California at Berkeley, where he was the director of several laboratories, associate director of the Lawrence Berkeley Laboratory and, since 1971, has been university professor of chemistry.

James D. Watson 1962 Physiology or Medicine



Like many of the great advances in science, the discovery of the structure of the genes depended on chance, the personal chemistry between researchers, and the work of many other colleagues who produced supporting information.

In 1951, Dr. Watson had moved to Cambridge University in England to continue his postdoctoral work when he met Dr. Francis H.C. Crick and Dr. Maurice H.F. Wilkins. Watson had become convinced that gene replication could only be understood when the structure of deoxyribonucleic acid, the chemical that makes up genes, was known.

Working with x-ray diffraction data on crystals of DNA produced by Dr. Rosalind Franklin, the team literally cut out cardboard models of DNA's subunits, and put them together in different ways until they came up with a model that fit the diffraction data. Their model was a double helix with pairs of nucleotide subunits turned inward like the rungs on a twisted ladder.

In a single-page paper published in Nature magazine, Drs. Watson and Crick literally changed the face of biology. The discovery of DNA's structure led to the unravelling of many fundamental questions in biology, such as how DNA controlled the production of proteins and how DNA itself was replicated.

Born in Chicago in 1928, Dr. Watson received a B.S. in zoology in 1947 from the University of Chicago. He received his Ph.D. from the University of Indiana in 1950 after working on the effects of x-rays on the multiplication of bacterial viruses. He worked at Cambridge University from 1951 to 1953, and then spent two years at the California Institute of Technology. From 1955 to 1976, he was a professor at Harvard University.

Since 1968, Dr. Watson has been director of the Cold Spring Harbor Laboratory on Long Island.

Konrad E. Bloch 1964 Physiology or Medicine

Understanding how the body makes and uses fatty acids and cholesterol has had a profound impact on the treatment and prevention of major disorders, especially heart disease. Dr. Bloch and his fellow Nobel laureate, Feodor Lynen, were the first to elucidate the fundamental mechanisms for fat metabolism.

The early work showed that one important precursor of cholesterol was acetic acid. Dr. Bloch worked through the steps in the biosynthesis of sterols, from acetic acid to squalene to the cyclization of squalene to lanosterol, leading to the intermediates of lanosterol and to cholesterol. He also contributed to the understanding of the biosynthesis of glutathione and of fatty acids. This work laid the basis for the development of "enzyme suicide" inhibition as a rational approach to drug design.

Born in Neisse, Germany, in 1912, Dr. Bloch came to the United States in 1936 after studying chemical engineering in Munich. In 1938, he received his Ph.D. in biochemistry at Columbia University. Working with the late Rudolf Schoenheimer, he pioneered metabolic investigations with the aid of radioactive isotopes. His work involved labeling compounds with "heavy hydrogen," then a new technique that he helped perfect.

He joined the faculty of Columbia and later that of the University of Chicago. In 1954 he was named Higgins Professor of Biochemistry at Harvard University, where he carried out many of his experiments on fat and sterol biosynthesis. In 1982, he was named the Newton-Abraham Visiting Professor and Fellow of Lincoln College, Oxford.

Charles B. Huggins 1966 Physiology or Medicine

After a quarter-century of studying the relationship between cancer and hormones, Dr. Huggins discovered that androgens (male hormones) stimulated the growth of prostate cancer cells and that castration or the use of female sex hormones could shrink prostatic cancer. This led to the first successful chemotherapy for malignancy in humans.

Dr. Huggins's work led to the hormone-dependent cancer theory, which has been shown to play a role in breast cancer. His other anticancer work has included the experimental production of leukemia and mammary cancer in animals so that these diseases can be studied under controlled conditions. From these laboratory experiments, Dr. Huggins has developed hormone treatments for at least seven types of human cancer.

Trained as a surgeon, research became the passion of his life. He once said: "One pits his wits against apparently inscrutable Nature. She can refuse to speak, but she cannot give a wrong answer. Her vocabulary consists only of three words — yes, no, and maybe. It is the genius of research to frame the question so simply that a conditional answer is prohibited."

Born in 1901 in Halifax, Canada, he later became a U.S. citizen. Dr. Huggins received his B.S. in 1920 from Acadia University in Nova Scotia, and his M.D. in 1924 from Harvard University. From 1927 to the present, he has worked at the University of Chicago Medical School.

George Wald 1967 Physiology or Medicine

Born in New York City in 1906, Dr. Wald received his B.S. in zoology from New York University in 1927. He received his Ph.D. in zoology from Columbia University in 1932. At Columbia he was a student and research assistant of Professor Selig Hecht.

On receiving his Ph.D., Dr. Wald was awarded a National Research Council Fellowship in Biology (1932-1934), and began working in the laboratory of Otto Warburg in Berlin-Dahlem, where Dr. Wald first identified vitamin A in the retina. Vitamin A had just been isolated in the laboratory of Paul Karrer in Zurich, where Wald completed the identification. Then he worked in the laboratory of Otto Meyerhof at the Kaiser Wilhelm Institute in Heidelberg. The second year of the Fellowship was spent at the Department of Physiology of the University of Chicago.

Dr. Wald came to Harvard in the fall of 1934 as a tutor in biochemical sciences and has been there ever since: as instructor and tutor in biology (1935-1944); associate professor (1944-1948); and professor, receiving the Higgins Chair in Biology in 1968. Dr. Wald is now Higgins Professor of Biology Emeritus.

He was awarded the Nobel Prize in Physiology or Medicine in 1967, jointly with Drs. R.A. Hartline and H.K. Granit.

Along with the many awards he has won, Dr. Wald was elected to the National Academy of Sciences in 1950 and to the American Philosophical Society in 1958. He is a Fellow of the American Academy of Arts and Sciences in Boston and the Optical Society of America. In 1963-1964 he was a Guggenheim Fellow, spending the year at Cambridge University, England, where he was elected an Overseas Fellow of Churchill College. He is also an Honorary Member of the Cambridge Philosophical Society (1969).

Robert W. Holley 1968 Physiology or Medicine

The genetic code resides deep in a cell's nucleus, far from the protein-synthesizing machinery that puts the genetic blueprint into action. A number of researchers sought the connection between deoxyribonucleic acid and the order of a protein's amino acids. Three forms of ribonucleic acid, a chemical cousin of the gene itself, play key roles — one carries the message from the DNA, messenger RNA; one is incorporated into protein factories called ribosomes; and a third, transfer RNA, carries amino acids into the ribosomes according to the sequence specified by the messenger RNA.

Dr. Holley was one of the scientists trying to understand that relationship. He spent a decade first isolating and then determining the exact structure of the transfer RNA that carries alanine. By 1964, he had worked out the exact order of the nucleotides in the alanine transfer RNA, a discovery that opened up a deeper understanding of protein synthesis.

Born in Urbana, Illinois, in 1922, Dr. Holley received his A.B. in chemistry from the University of Illinois in 1942. In 1947, he earned his Ph.D. in organic chemistry while working with Professor Alfred T. Blomquist at Cornell University. He also worked with Professor Vincent du Vigneaud at Cornell University Medical College, where he participated in the first chemical synthesis of penicillin. He spent 20 years associated with Cornell University, eventually becoming chairman of the biochemistry department from 1965 to 1966. The work on the alanine transfer RNA was done at a U.S. Department of Agriculture laboratory on the Cornell campus.

Since 1968, Dr. Holley has worked at the Salk Institute in La Jolla, California, in recent years studying the factors that control cell division in mammals.

H. Gobind Khorana 1968 Physiology or Medicine

Dr. Khorana, like other scientists in the early 1960s, including co-laureates Dr. Marshall W. Nirenberg and Dr. Severo Ochoa, turned his analytical skills to deciphering the genetic code, then one of the hottest races in science. Although Dr. Nirenberg generally is credited with cracking the code first — various arrangements of the four different types of DNA subunits called nucleotides that specify which amino acids are placed in a protein — Dr. Khorana shares the honor because he was the first to succeed in synthesizing artificial polynucleotides — bits of genes.

He also extended Nirenberg's nitrocellulose binding technique for testing each of the 64 possible combinations of nucleotide triplets. Those studies helped prove that each set of three nucleotides in the gene specifies a single amino acid in the protein. Dr. Khorana showed that the triplets do not overlap and that in protein synthesis, they are read in sequence without gaps between them. In addition to helping crack the genetic code, Dr. Khorana was the first to synthesize an artificial gene. His earlier work included studies on alkaloids and the synthesis of coenzyme A.

Born in Raipur, India, in 1922, Dr. Khorana later became an American citizen. He received his B.Sc. in 1943 and his M.Sc. in 1945 from the Punjab University. He earned his Ph.D. from Liverpool University in 1948. Since 1970, Dr. Khorana has been Sloan Professor of Chemistry and Biology at the Massachusetts Institute of Technology.

Marshall W. Nirenberg, Ph.D. 1968 Physiology or Medicine

The structure of deoxyribonucleic acid (DNA), the chemical essence of the gene, was identified in 1953, but it left a key question unanswered. How did the four types of nucleotide subunits that composed the DNA helix determine the sequence of the 20 amino acids that make up all proteins?

In the summer of 1957, Dr. Marshall Nirenberg came to the National Institutes of Health as a postdoctoral fellow and became intrigued by the problem. As is often the case, a simple, elegant experiment provided the first critical clue to cracking the code. Dr. Nirenberg's work suggested that every combination of three DNA subunits represented a different amino acid. He presented the first few codes in Moscow in the summer of 1961 and a race immediately began for the rest of the 64 possible codes.

Several laboratories, many better equipped than Dr. Nirenberg's two-man operation, began to fill in more of the 64 possible combinations of nucleic acids. Researchers from other NIH laboratories pitched in to help Nirenberg compete, often working around the clock. By December, 1961, Dr. Nirenberg's group published a large number of tentative code words. The race was won, though it took several more years to fill in all of the details.

Dr. Nirenberg shared the Nobel Prize for Physiology or Medicine with Drs. Robert Holley and H. Gobind Khorana.

Dr. Nirenberg was born in New York City in 1927. He graduated from the University of Florida in 1948 with a B.S. in zoology and chemistry and received an M.S. in 1952. He earned his Ph.D. in biochemistry from the University of Michigan in 1957. Dr. Nirenberg is the chief of the Laboratory of Biochemical Genetics in the National Heart, Lung and Blood Institute at the National Institutes of Health. He is currently studying the genes involved in the development of the brain and nervous system.

Salvador E. Luria 1969 Physiology or Medicine

Dr. Luria, along with Dr. Max Delbruck of the California Institute of Technology, with whom he shared the Nobel Prize, was one of the fathers of the phage group, a band of researchers who worked out the replication mechanism and the genetic structure of viruses that infect bacteria, and the genetics of bacteria themselves. Dr. Luria's work laid the foundation for what eventually became the field of molecular biology.

By studying generation after generation of different viruses while developing techniques to purify them, Dr. Luria was the first to discover that genetic mutations in viruses caused the proteins on their surfaces to change, allowing them to escape attacks by the body's immune system and allowing the viruses themselves to attack cells that they previously could not enter. These sorts of mutations explain how new strains of influenza arise from time to time, causing epidemics among populations that are not protected against them.

Years before biologists called for a moratorium on some types of genetic engineering research in the mid-1970s, Dr. Luria expressed hope about the promise of the emerging field of molecular biology, but also concern about the consequences of humans being able to tinker with their own genes. Dr. Luria has long been part of the social conscience of the scientific community, championing a variety of causes, including the anti-war movement during Vietnam, a position that caused his name, along with those of other scientists, to turn up on a blacklist put together by the federal government.

Born in Turin, Italy, in 1912, Dr. Luria received his M.D. from the University of Turin in 1935, and went on to become a specialist in radiology at the University of Rome. After serving in the Italian Army from 1935 to 1938, he became a researcher at the Institut du Radium in Paris, and then moved to the United States, where he became a citizen in 1947. From 1940 to 1942, he was a researcher at Columbia University, then became a professor at Indiana University from 1942 to 1950 and at the University of Illinois from 1950 to 1959. Since 1959, he has been the Sedgwick Professor of Biology, later institute professor and director of the Center for Cancer Research at the Massachusetts Institute of Technology.

Julius Axelrod 1970 Physiology or Medicine

Nerve cells do not touch each other. They communicate through neurotransmitters, chemicals squirted into the synapses, the spaces between the ends of nerve cells. But little was known about how neurotransmitters were formed, regulated or inactivated. Dr. Axelrod was the first to define the mechanisms that regulate the formation and inactivation of noradrenalin, one of the brain's most important neurotransmitters. This discovery led to a better understanding of human behavior and has disclosed the action of psychoactive and antidepressant drugs.

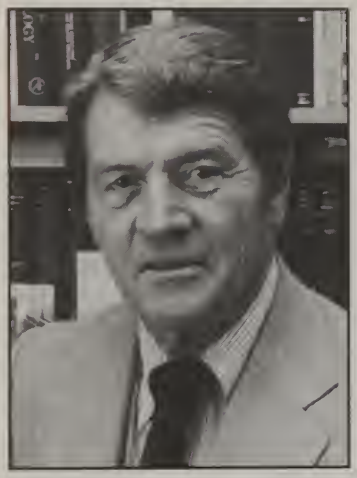
A person suffering from severe depression may, for example, have a shortage of available noradrenalin. Neurotransmitters, once secreted, are quickly broken down to prevent them from continuously stimulating a nerve, Dr. Axelrod showed. Antidepressant drugs have been designed to reduce the speed with which noradrenalin is inactivated, giving a more near-normal firing of those neurons. He also discovered the biochemical actions of the pineal gland and enzymes that form and metabolize neurotransmitters, hormones, and that detoxify drugs.

Dr. Axelrod, along with Bernard Brodie, contributed to the development of the widely use pain-killing drug Tylenol.

Born in the ghettos of New York City in May, 1912, Dr. Axelrod received his B.S. from the City College of New York in 1933 and his M.A. from New York University in 1941. Because he lacked sufficient money to continue his education, he worked in a food-testing laboratory. In 1950, he moved to the National Institute of Mental Health, and, believing he could not get a promotion without one, he went back for his Ph.D., which he received from George Washington University in 1955.

Recently retired as chief of the NIMH Section on Pharmacology, he continues to perform research as a guest worker at the National Institute of Mental Health and acts as a consultant to a biotechnology company and several nonprofit organizations.

Christian B. Anfinsen 1972 Chemistry



Genes carry information linearly, like a piece of audio tape. But cells and bodies are three-dimensional, and so are the proteins that make them up. How is it that this linear information in the gene could result in three-dimensional proteins that are able to perform a biological task?

Working with ribonuclease, an enzyme that breaks up molecules of ribonucleic acid, Dr. Anfinsen was able to successfully show that the three-dimensional, globular shape of the protein, and its catalytically active cleft, were determined by the sequence of the amino acids in the protein. Earlier workers had shown that the sequence of a protein's amino acids was determined by the sequence of nucleotides in the gene. Dr. Anfinsen's experiments helped elucidate the process of protein folding within the cell by which proteins attain their three-dimensional shapes.

Born in Monessen, Pennsylvania, in 1916, Dr. Anfinsen received his B.A. from Swarthmore College in 1937 and an M.S. in organic chemistry from the University of Pennsylvania in 1939. He was a visiting investigator at the Carlsberg Laboratory in Copenhagen during 1939 and 1940. He received his Ph.D. from Harvard University in 1943, and for seven years was an instructor and assistant professor of biological chemistry at the Harvard Medical School.

During 1947 and 1948, he was a senior fellow of the American Cancer Society at the Medical Nobel Institute.

In 1950, Dr. Anfinsen became chief of the Laboratory of Cellular Physiology and Metabolism in what is now the National Heart, Lung and Blood Institute of the National Institutes of Health. He later was chief of the Laboratory of Chemical Biology in what is now the National Institute of Diabetes and Digestive and Kidney Diseases. Since 1982, Dr. Anfinsen has been a professor of biology at the Johns Hopkins University.

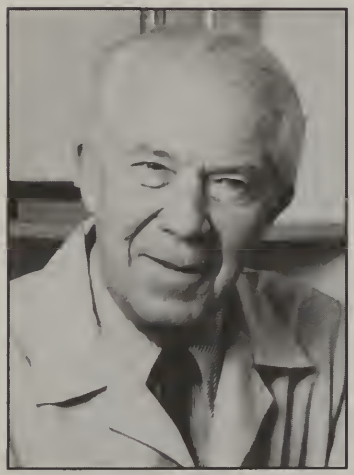
Gerald M. Edelman 1972 Physiology or Medicine

Gerald M. Edelman was born in New York City in 1929. He earned his B.S. degree at Ursinus College, and an M.D. at the University of Pennsylvania. He spent a year at the Johnson Foundation for Medical Physics, and after a medical house officership at the Massachusetts General Hospital, he served as a captain in the Army Medical Corps. He earned his Ph.D. at the Rockefeller Institute in 1960 where he has remained throughout his distinguished career. At present, he is Vincent Astor Professor at the Rockefeller University.

Edelman has a broad range of intellectual interests both in and outside of science. He has made significant contributions in biophysics, protein chemistry, immunology, cell biology, and neurobiology. His early studies on the structure and diversity of antibodies led to the Nobel Prize for Physiology or Medicine in 1972. He then turned his interest to mechanisms involved in the regulation of primary cellular processes, particularly the control of cell growth and the development of multicellular organisms. In the course of this work he has focused on cell-cell interactions in early embryonic development and in the formation and function of the nervous system. These interests led to the discovery of cell adhesion molecules (CAMs), the function of which is of great significance for the development and morphology of brain structures.

In addition to the Nobel Prize, Gerald Edelman has been the recipient of numerous awards and honors including many honorary degrees, and memberships in the National Academy of Sciences, the American Philosophical Society, and the Academy of Sciences, Institute of France. In addition, he is director of the Neurosciences Institute and scientific chairman of the Neurosciences Research Program.

Christian de Duve 1974 Physiology or Medicine

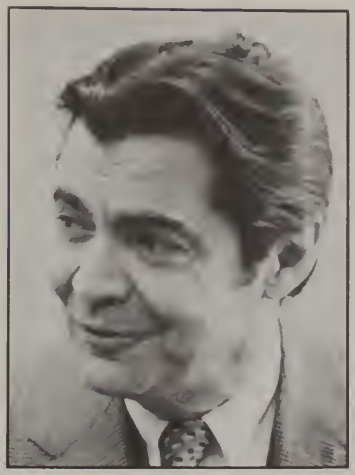


Individual cells, like the human body itself, are composed of different organs, or organelles, that perform the biological activities needed for survival. Dr. de Duve, working with the cell fractionation techniques developed by fellow Nobel winner, Dr. Albert Claude of Rockefeller University in New York, and combining them with biochemical analysis and electron microscopy, discovered two of the cell's organelles: lysosomes and peroxisomes. Lysosomes are the cell's stomach. They keep the cell's powerful degradative enzymes contained in sacs within the cell's cytoplasm so materials taken up from both outside and inside the cell can be safely digested. Peroxisomes play a central role in the metabolic production and breakdown of hydrogen peroxide. In later work, Dr. de Duve sought to understand the relationship between lysosomes and diseases.

Born in England in 1917, Dr. de Duve, a citizen of Belgium, was educated at the University of Louvain, receiving his M.D. in 1941, the equivalent of a Ph.D. in 1945, and a Master's degree in chemistry in 1946. He conducted research in Stockholm and St. Louis before becoming a professor of biochemistry at the University of Louvain in 1951. In 1961, he also became a professor at Rockefeller University, and, in 1974, he became the Andrew W. Mellon Professor at Rockefeller.

He now divides his time between New York and Brussels where, in 1975, he created the International Institute of Cellular and Molecular Pathology, in close collaboration with Rockefeller University. The institute's work concentrates on basic cellular and molecular biology, biochemistry, and immunology, and on the applications of these disciplines to medicine.

George E. Palade 1974 Physiology or Medicine



Many cellular structures are far too small to be perceived even by the most powerful light microscope. The discovery that a stream of electrons can be used to "see" structures opened new windows into the cell that Dr. Palade learned to exploit, thus ushering in a new era in cellular anatomy.

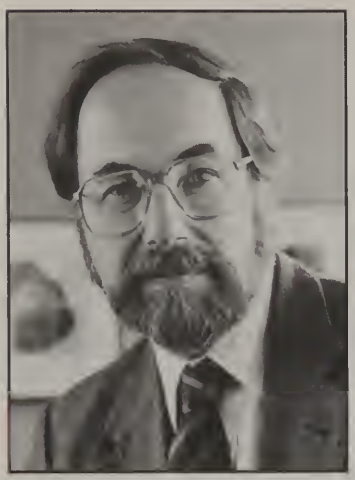
By using centrifugation techniques to isolate purified cell components and by improving preparation techniques for electron microscopic studies, Dr. Palade and his colleagues discovered ribosomes, the protein-synthesizing factories of the cell, for which he received the Nobel Prize.

Continuing the work of the late Dr. Albert Claude, a co-laureate, Dr. Palade combined structural studies of cells with biochemical assays of cell fractions to discover the ribosome and identify its function. He also defined the fine structure of the mitochondria (the cell's power plant) and, in collaboration with Dr. Keith Porter, studied the structure of the endoplasmic reticulum in different cell types. They established that the endoplasmic reticulum is a network of membrane-bound channels extending from the nucleus through most of the cytoplasm. The channels are used for the transport and sorting of proteins produced by the ribosomes attached to their membranes.

They then used the same integrated structural and biochemical research approach soon after to decipher the processes and define the pathways used by cells to synthesize secretory and membrane proteins and to direct them to their proper destinations.

When Dr. Palade received an honorary degree from Columbia University, President Michael Sovern said, "Your early work established the isolation and characterization of subcellular components as a major research tool, which it has remained to this day. You subsequently solved the major problem of fixation of tissues for electron microscopy, enabling that technique to become a critical tool for research in biology and for diagnosis in medicine. . . . Your achievements have continued unabated." Born in Romania in 1912, Dr. Palade later became a U.S. citizen. He received his M.D. from the School of Medicine of the University of Bucharest in 1940. After serving in the Romanian Army Medical Corps during World War II, he came to the Rockefeller University in New York in 1946, where he met Dr. Claude. In 1973, Dr. Palade became a senior research scientist in the Department of Cell Biology at Yale University, where he continues to explore the implications of his work for pathology and clinical medicine.

David Baltimore 1975 Physiology or Medicine



In 1975, at the age of 37, David Baltimore became one of the youngest recipients of the Nobel Prize in Physiology or Medicine, honored along with Howard Temin for their simultaneous but independent discovery of reverse transcriptase, a viral enzyme able to copy the information in RNA into DNA. It was a discovery that elucidated the mystery of how viruses that store their information in RNA managed to infect cells that store their genes in DNA, thus challenging existing dogma. They shared the prize with Renato Dulbecco.

Dr. Baltimore is a leader and spokesperson for science on many issues, including genetic research, priorities for national research, and on matters of international concern, such as biological warfare and the regulation of science. He was cochairman of a major study of AIDS, sponsored by the National Academy of Sciences and the Institute of Medicine. The result, **Confronting AIDS,** was published in 1986.

Dr. Baltimore's current research covers three areas: cancer-inducing viruses, the immune system, and poliovirus. In each he seeks to define the biochemical events underlying changes in gene expression and gene structure in the mammalian cell. He has a special interest in the immunology of AIDS.

After receiving his B.A. with honors in chemistry from Swarthmore College in 1960, he went to MIT to begin graduate studies. A year later he went to Rockefeller University, from which he received a Ph.D. in biology in 1964. He did postdoctoral research at MIT and at the Albert Einstein College of Medicine, then became a research associate at the Salk Institute in 1965. In 1968, he returned to MIT as an associate professor, became professor of biology in 1972, and was appointed American Cancer Society Research Professor in 1973. In 1974, he joined the staff of the MIT Center for Cancer Research, where he remained until he was named director of the Whitehead Institute, an independent research institution affiliated with MIT, in 1982.

Besides his position as director of the Whitehead Institute, Dr. Baltimore is also a professor of biology at MIT.

Since the early part of the century, researchers knew that some animal viruses could cause cancer, but no one understood how. Dr. Dulbecco performed pioneering work describing the interaction between tumor-causing viruses and the genetic material of the infected cell. He worked out many of the techniques used by researchers to study the molecular biology of animal viruses, including techniques used by co-laureates Drs. David Baltimore and Howard Temin — both of whom worked under Dr. Dulbecco at one point in their careers — to discover how RNA viruses infected and transformed normal cells into cancer cells. Dr. Dulbecco also made significant discoveries about the mechanisms by which DNA tumor viruses transformed normal cells into cancer cells.

Born in Catanzaro, Italy, in February 1914, Dr. Dulbecco received his M.D. from the University of Turin in 1936. After being wounded on the Russian front during World War II, he was sent back to Turin to recuperate. When the German Army took over following the collapse of Mussolini's government, Dr. Dulbecco joined the resistance. After liberation, he served on the first postwar Turin City Council, but eventually returned to research.

In 1946, Dr. Salvador Luria, on a visit to Turin, encouraged Dr. Dulbecco to come to the United States. In 1947, he began work with Dr. Luria at Indiana University. He joined the California Institute of Technology in 1949 and stayed there until moving to the Salk Institute in La Jolla, California, in 1962. In 1971, he joined the Imperial Cancer Research Fund in London, but returned to the Salk Institute as the Senior Clayton Foundation Investigator in 1977 where he continues his research today.

Howard M. Temin 1975 Physiology or Medicine

Initially, and for the next six years, no one believed him. In 1964, Dr. Temin first introduced his hypothesis that the genetic information of the Rous sarcoma virus was converted from the RNA genes of the virus to a DNA form, and then the viral DNA was integrated into the infected cell. No one believed him because the hypothesis violated the Central Dogma of biology, which said that biological information flowed from DNA to RNA to protein.

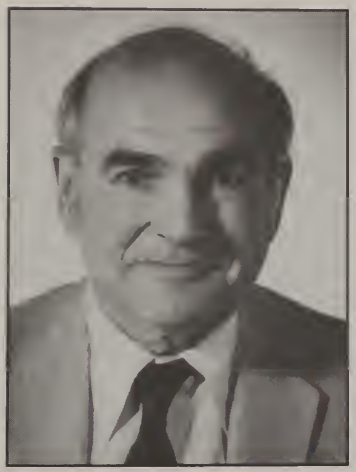
RNA usually was thought of as a messenger carrying the information for the sequence of amino acids in proteins from the DNA to the protein-making machinery. To suggest that information flowed the other way, back to DNA, violated the Central Dogma.

But then Dr. Temin and, independently, Dr. David Baltimore from the Massachusetts Institute of Technology, discovered the viral enzyme — known as reverse transcriptase — that literally copied the genetic information from RNA into DNA. The case was proved; the violated dogma was adjusted.

Reverse transcriptase has proved invaluable in the search for disease-causing genes and in the development of the genetic engineering industry, which now can produce previously rare proteins in nearly unlimited quantities. Dr. Temin also developed the provirus hypothesis for RNA viruses, which correctly described how some viruses can integrate their genes into the genetic material of the host cell and be inherited along with the other genes by the subsequent generations. The provirus can remain quiescent within the cell, produce new infectious viruses, or sometimes transform the cell into a cancer that grows uncontrollably.

Born in Philadelphia in 1934, Dr. Temin received his B.A. from Swarthmore College in 1955 and his Ph.D. from the California Institute of Technology in 1959, where he stayed for another year. In 1960, he moved to the McArdle Laboratory for Cancer Research in the medical school of the University of Wisconsin in Madison, where he has spent his entire academic and research career. During his time there, he became a full professor, then Wisconsin Alumni Research Foundation Professor of Cancer Research, and, in 1974, American Cancer Society Professor of Viral Oncology and Cell Biology.

Baruch S. Blumberg 1976 Physiology or Medicine



While studying genetic variations in human blood, Dr. Blumberg discovered an antigen in an Australian aborigine that reacted with an antibody in the blood of a transfused hemophilia patient. He and his colleagues subsequently showed that the antigen was on the surface of the hepatitis B virus, which causes diseases of worldwide importance. These include primary cancer of the liver, one of the most common cancers in the world.

The discovery had practical consequences: it revolutionized blood banking by providing a way to test donated blood to prevent transfusion-caused hepatitis. These tests are now routinely used to screen blood donors and have led to the prevention of certain kinds of posttransfusion hepatitis.

Blumberg and Millman introduced a vaccine to prevent hepatitis B infection that is now used widely among high-risk individuals, particularly health care workers and newborn children already infected with the virus. Its major use is in large national programs in the People's Republic of China, Taiwan, Korea, Gambia, and elsewhere, in which all newborns are vaccinated. A major rationale for these national campaigns is to reduce the risk for primary cancer of the liver.

Born in New York in 1925, Dr. Blumberg received his B.S. in physics from Union College, in 1946 and his M.D. from the College of Physicians and Surgeons of Columbia University in 1951. Oxford University (Balliol College), awarded him a Ph.D. in biochemistry in 1957. From 1957 to 1964, he was chief of the Geographic Medicine and Genetics section of the National Institutes of Health. He then became associate director for Clinical Research, Fox Chase Cancer Center, in Philadelphia where he now is vice president for Population Oncology. Dr. Blumberg is also a university professor of medicine and anthropology at the University of Pennsylvania.

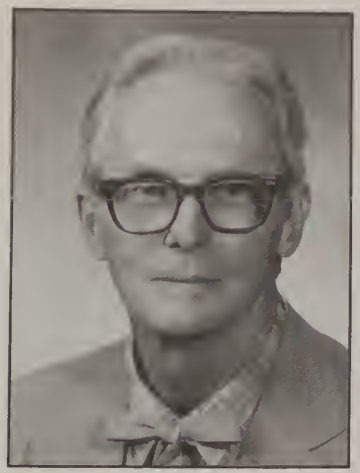
Dr. Carlton Gajdusek 1976 Physiology or Medicine

Dr. Gajdusek's work achieved a breakthrough that revolutionized thinking in microbiology and neurology. With his associates, he showed that a "slow" viral infection was responsible for kuru, an exotic chronic degenerative disease. They went on to relate their findings to a wide range of other degenerative neurological diseases, "with incalculable implications for all of medicine, especially as it applies to the basic process of degenerations and aging." In his Nobel speech, he summed up some of the implications of his studies. "For neurology, specifically, we have considerable new insights into the whole range of presenile dementias and, in particular, the large problems of Alzheimer's disease and the senile dementias."

His travels and studies of disease in exotic areas started at the Institut Pasteur in Teheran in 1952. He worked on epidemic diseases in Iran, Afghanistan, Turkey, India, and South America. Most important was his study of kuru in New Guinea, which demonstrated the then unknown phenomenon of a "slow" viral infection, taking years to be evident and always leading to death. The viruses of kuru, senile virus dementia, and scrapie are unlike any others yet described: they are resistant to almost everything that inactivates other viruses, and they contain no nonhost protein. Fortunately, the threat of kuru is disappearing, not because of direct medical intervention, but because of social change. Ritual cannibalism is no longer practiced as a rite of mourning, and this has meant that the contamination from brain tissue of kuru victims heavily infected with the virus has stopped.

Dr. Gajdusek was born in Yonkers, New York, in 1923, to a Slovak father and a first-generation Hungarian-American mother. His interest in science was encouraged by his aunt, Dr. Irene Dorbroczki and by Dr. William J. Youden of the Boyce Thompson Institute Laboratories in Yonkers, where, while still a teenager, he was the first to synthesize the weed killer 2,4-D. He took his B.S. in biophysics from the University of Rochester, summa cum laude, in 1943, his M.D. from Harvard in 1946, and postdoctorate training in physical chemistry at the California Institute of Techonology.

William N. Lipscomb 1976 Chemistry



The bonds between molecules and their interactions are the essence of chemistry. Dr. Lipscomb developed a model to explain the molecular structure and chemical bonding of boranes, and developed an explanation of how two electrons can bind together three atoms.

Long interested in the relationship between structure and function, Dr. Lipscomb was among the first to describe the three-dimensional structure of enzymes and other proteins. He used nuclear magnetic resonance to study complex molecules, and low-temperature x-ray diffraction to work out the three-dimensional structure of biochemical crystals — including enzymes.

Born in Cleveland in 1919, Dr. Lipscomb received his B.S. from the University of Kentucky in 1941. He entered the California Institute of Technology, where he began studying physics, but, under the influence of Dr. Linus Pauling, switched to chemistry; he received his Ph.D. in 1946. Dr. Lipscomb then joined the Chemistry Department at the University of Minnesota, where he became a full professor and chief of the Physical Chemistry Division.

In 1959, Dr. Lipscomb became professor of chemistry at Harvard University and, in 1971, he was named Abbott and James Lawrence Professor of Chemistry.

Roger Guillemin 1977 Physiology or Medicine

As so often is the case, an intense interest in a branch of research began with an inspiring lecture. Hans Selye had come to Paris in the late 1940s to lecture about "his alarm reaction and the endocrinology of the general adaptation syndrome," Dr. Guillemin wrote. "I went to hear him. The magnetism of the man was extraordinary."

As a consequence, Dr. Guillemin moved to Dr. Selye's newly created Institute of Experimental Medicine and Surgery at the University of Montreal and began learning experimentation in endocrinology while completing work on his M.D. Dr. Guillemin received his M.D. from the Faculty of Medicine of Lyon, related to the University of Dijon, France, in 1949. He continued his work in Montreal and later received his Ph.D. in physiology from the University of Montreal in 1953.

After settling at Baylor University College of Medicine, where he stayed from 1953 to 1970, Dr. Guillemin searched for the neuroendocrine secretions of the hypothalamus, a part of the brain that through the pituitary gland controls all endocrine glands, including the thyroid, gonads, and the adrenal cortex. His work at Baylor, in collaboration with co-laureate Dr. Andrew V. Schally, resulted in the identification and synthesis of thyrotropin-releasing factor, luteinizing-hormone releasing factor and a factor inhibiting the secretion of growth hormone.

Dr. Guillemin was born in 1924 in Dijon, France, and later became a U.S. citizen.He received a B.A. in 1941 and a B.Sc. in 1942 from the University of Dijon. After working in Montreal and Houston, he moved to the Salk Institute in La Jolla, California, in 1970, where he remains today.

Andrew V. Schally 1977 Physiology or Medicine

Dr. Schally was in a race. He and Dr. Roger Guillemin each struggled to be the first to identify, isolate, and synthesize the hypothalamic hormones and then apply them clinically. Corticotropin-releasing factor (CRH) was discovered in 1955. Thyrotropin-releasing hormone (TRH) was identified in 1966, and luteinizing hormone-releasing hormone (LH-RH) in 1971.

Dr. Schally described the 1971 announcement of LH-RH as one of the most exciting moments of his life because it established him as the victor in a race to be the first to isolate a hormone that has proved to be the critical link between reproductive functions and the brain's pituitary gland. The discovery had important diagnostic and therapeutic applications.

His work with brain hormones continued including investigations into the use of antagonists of LH-RH, work with prolactin release-inhibiting factor, somatostatin and its analogs, and attempts to understand the connection between the hypothalamus and obesity. Since 1978, Dr. Schally has been working on hormone-dependent cancers, and is now the chief of the Endocrine, Polypeptide and Cancer Institute. Some of the new approaches to cancer treatment he developed are now the subject of clinical trials.

Born in Wilno, Poland, in 1926, Dr. Schally initially was a Canadian citizen before becoming a citizen of the United States. He received a B.Sc. in biochemistry from McGill University in 1955 and a Ph.D. in 1957. Like his colaureate Dr. Guillemin, Dr. Schally did research at the Baylor University College of Medicine in Houston, Texas.

Dr. Schally came to New Orleans, Louisiana, in 1962 to organize the Veterans Administration-Tulane University laboratory for hypothalamic research. He became a full professor of medicine at Tulane in 1967 and section head and professor of experimental medicine in 1980.

Rosalyn S. Yalow, Ph.D. 1977 Physiology or Medicine

Antibodies — proteins produced by the body to fight infections — have the ability to specifically recognize the shapes of different molecules. This makes antibodies very selective. Antibodies also are so sensitive that they can identify and bind a molecule even if it is present in very small concentrations.

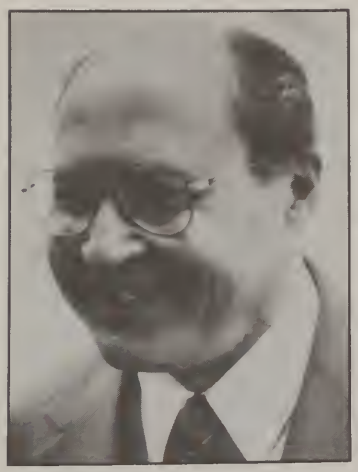
But it took Dr. Yalow, working with Dr. Solomon A. Berson, to figure out how to combine antibodies with radioactive tracers to create radioimmunoassay, a technique that allows scientists to measure incredibly small quantities (down to a picogram, or 10 to the minus 12 grams) of hundreds of different biological substances. Dr. Yalow initially used the technique to measure insulin levels in diabetics, leading to the discovery that in adult onset diabetes the blood level of insulin can be high but its sugar-metabolizing action is blocked. The technique has been used to detect many other compounds in the body, including infectious agents such as the hepatitis virus, concentrations of antibiotics and other drugs, and growth hormones.

Dr. Yalow was born in 1921 and raised in New York City. Committed to mathematics by seventh grade and excited by chemistry in high school, she planned to become a chemist when she entered Hunter College, where physics also caught her interest. She graduated in 1941 with a Bachelor's degree in both chemistry and physics.

Although she wanted to study physics in graduate school, she was pressured into taking secretarial courses and landed a job as secretary for Dr. Rudolph Schoenheimer, a well-known biochemist at Columbia University's College of Physicians and Surgeons. Her secretarial career, however, was short-lived because Dr. Yalow was offered a graduate assistantship in the Physics Department at the University of Illinois — the first woman in the program since 1917 — where she earned an M.S. in 1942 and a Ph.D. in 1945.

She came back to New York City in 1945 and joined the Bronx Veterans Administration Hospital in 1947, where she has spent most of her professional life. In 1972, she became a senior medical investigator at the VA, and in 1986 she was also named Solomon A. Berson Distinguished Professor at Large at Mount Sinai School of Medicine.

Daniel Nathans 1978 Physiology or Medicine



Dr. Nathans had been studying the regulation of protein synthesis directed by a bacterial virus when he developed an interest in viruses that cause tumors in animals. While he was on sabbatical in 1969 exploring the molecular biology of tumor viruses, his Johns Hopkins colleague Hamilton O. Smith wrote to tell him that he had purified an enzyme from bacteria that cut long molecules of DNA — the chemical that carries genetic information — at specific sites. Seeing the significance of this discovery, Dr. Nathans on his return to Johns Hopkins began to use Smith's enzyme and other restriction endonucleases (identified later as "chemical scissors") to break up the DNA of a tumor virus into distinct fragments that could be separated by electrophoresis. These techniques allowed him to isolate individual genes and map them on the viral chromosome and to biochemically construct site-specific mutants of the virus. Extensions of these methods have been widely used to analyze viral and cellular genomes, to recombine genetic elements, and to identify genes related to human diseases.

Dr. Nathans was born in Wilmington, Delaware, in 1928. He received his B.S. in chemistry at the University of Delaware and his M.D. from Washington University in St. Louis, where he worked with Oliver H. Lowry. After completing a medical residency, he joined Fritz Lipmann's laboratory at the Rockefeller University. Since 1962, he has been a faculty member at Johns Hopkins. Dr. Nathans is currently university professor of molecular biology and genetics and senior investigator of the Howard Hughes Medical Institute.

Hamilton O. Smith 1978 Physiology or Medicine

In the microscopic battles between bacteria and the viruses that infect them (bacteriophages), one of the bacteria's most potent defenses are enzymes that selectively dice up the deoxyribonucleic acid, the chemical essence of the genes — of the invading virus while leaving the bacteria's own DNA intact. These enzymes are able to recognize the specific sequence of DNA subunits (called nucleotides) that are present in the viruses, but not in the bacterial DNA.

Dr. Smith discovered the first of these enzymes, now called restriction endonucleases, in the bacteria *Haemophilus influenzae*. Today, more than a hundred restriction endonucleases of different specificities are known. Fellow Johns Hopkins University researcher Dr. Daniel Nathans, and subsequently other scientists, discovered ways to use the enzymes to perform previously impossible studies on genetic material, chopping the DNA into manageable sizes and cloning it into carrier molecules (called plasmids) that can be used to reproduce the specific gene endlessly.

These techniques helped give rise to the entire biotechnology/gene engineering industry that already is producing such important pharmaceuticals as insulin for diabetics, growth factors, clotting factors, and even vaccines —such as the one against hepatitis B virus infections.

Born in New York City in 1931, Dr. Smith received his A.B. from the University of California at Berkeley in 1952 and his M.D. from Johns Hopkins University Medical School in 1956. He studied human and viral genetics while serving in the U.S. Navy, and by 1962, he had focused his research on molecular genetics. In 1967, Dr. Smith joined the Department of Microbiology at the Johns Hopkins Medical School and began the work that eventually led to the isolation of the restriction endonucleases.

Herbert C. Brown 1979 Chemistry

Dr. Brown's breakthrough discovery of hydroboration enabled chemical synthesis of previously impossible purity and yields. This basic discovery allows wide-scale production of many biologically active substances, including synthetic amino acids, carbohydrates, hormones, vitamins and steroids.

Dr. Brown was born in London in 1912 to Jewish immigrants from the Ukraine. The family moved to Chicago in 1914, where his father worked as a carpenter and later opened a hardware store. When his father died in 1926, Dr. Brown left high school to work in the store. His mother, seeing his lack of interest in business and his devotion to reading, soon took over the shop keeping and sent him back to school.

Graduating from high school in 1930 in the depths of the Depression, he was only able to attend college part-time. With encouragement from his chemistry instructors, he was in the first graduating class of Wright Junior College in 1935. He went on to the University of Chicago, where he received his B.S. in 1936 and his Ph.D. in 1938. After beginning his career at Wayne State University in Detroit, he went to Purdue in 1947 as professor of chemistry, becoming in 1978 the Wetherill Research Professor Emeritus with honors from around the world. He maintains an active research program, achieving his one-thousandth publication in October 1986.

Allan M. Cormack 1979 Physiology or Medicine

Enter nearly any radiology department in any good-sized hospital in America and you will find a CAT scanner, a diagnostic imaging system that produces slice-like images of the body's soft internal tissues that could never be seen before without surgery. The CAT, or computerized axial tomography, scanner revolutionized diagnostic radiology and has been called one of the most important advances in medical technology since the discovery of x-rays.

Dr. Cormack developed the mathematical equations necessary to reconstruct the data collected by the CAT scanner's array of x-ray beams into an image of the body's organs. Although he had been interested in problems related to CAT scanning in the 1950s and had published papers on it in the 1960s, few people realized the medical applications of his work. As a result, he did not begin full-time work on the calculations needed to perform CAT scans until the early 1970s, by which time fellow laureate, Godfrey N. Hounsfield, was developing the first practical CAT scanning system for general health care.

Born in Johannesburg, South Africa, in 1924, Dr. Cormack studied electrical engineering and received a B.Sc. in 1944 and an M.Sc. in 1945 from the University of Cape Town, where he was a professor of physics from 1946 to 1956. He came to Harvard University as a researcher in 1956, then moved over to Tufts University as a professor in 1957, where he remains today. He is now an American citizen.

Baruj Benacerraf understood well the difference between those who responded allergically to dust or mold and those who did not. He had suffered bronchial asthma as a child, an experience that instilled in him a deep curiosity about allergic phenomena.

Although his research career led him to laboratories around the world, he eventually settled at New York University, and, for a time, at the National Institutes of Health, where inbred strains of guinea pigs and mice helped Dr. Benacerraf and his colleagues discover the immune response, ***Ir,*** genes that regulate proteins on the surface of white blood cells. These genes play a central role in the manner in which the immune system recognizes the foreign proteins — known as antigens — of infectious agents such as viruses and bacteria.

From his animal experiments, Dr. Benacerraf concluded that the *Ir* genes were part of the body's major histocompatibility complex, a central set of genes that regulate the immune system. His key insights into the mechanisms of immunity have had implications for a number of diseases and for organ transplantation.

Born in Caracas, Venezuela, in 1920 to a Sephardic family originally from North Africa, he was educated in Paris until 1939, when his family fled the coming war. In 1940, he moved to New York City, eventually attending Columbia University to prepare for medical school. He received his M.D. from the Medical College of Virginia in 1945. After becoming an American citizen and serving as a physician in the U.S. Army, Dr. Benacerraf returned to Columbia to begin his research career in immunology in 1948. After spending some time in Paris, he moved to the Pathology Department of New York University in 1956, and in 1968, to the National Institutes of Health. He stayed at NIH for two years before moving for the last time to Harvard University, where he is chairman of the Pathology Department and president of the Dana Farber Cancer Institute.

Paul Berg 1980 Chemistry

The 1950s and 1960s had been an exciting time of rapid insight into the genetic chemistry — now called molecular biology — of simple prokaryotic organisms, the viruses and bacteria. But Dr. Berg wondered whether the genetic chemistry of higher organisms, the eukaryotes, including mammals, had the same organization.

Working with the mammalian virus SV40, Dr. Berg began using the then newly discovered restriction endonucleases, enzymes that selectively slice DNA into smaller pieces, to create a physical map of SV40's circular chromosome. The ability of SV40 to integrate its genes into the chromosomes of the cell it infects made Dr. Berg wonder whether it was possible to permanently introduce new genes into a cell.

To test that idea, he developed a procedure for joining two different DNA molecules together in the lab. Once the hybrid DNA was made, Dr. Berg's group learned how to put it into cells in ways that it would produce proteins encoded by the new DNA. This advancement helped lead to the development of the entire field of biotechnology, in which once scarce pharmaceutical proteins can now be made in nearly unlimited quantities.

Early concerns about the safety of introducing new genes into cells led Dr. Berg and others to call for a brief moratorium on certain kinds of experiments in the mid-1970s until certain safety questions could be answered. Since then, the moratorium has been lifted and the research judged to be safe.

Born in New York City in 1926, Dr. Berg received his B.S. from the Pennsylvania State University in 1948 and his Ph.D. from Western Reserve University in 1952. After postdoctoral studies with Herman Kalckar in Copenhagen, Dr. Berg worked with Dr. Arthur Kornberg at Washington University in St. Louis in 1953 and 1954 and then continued on his own there until 1959, when he moved to the Department of Biochemistry in the Stanford University School of Medicine. He is now the Willson Professor of Biochemistry at Stanford and director of the Beckman Center for Molecular and Genetic Medicine.

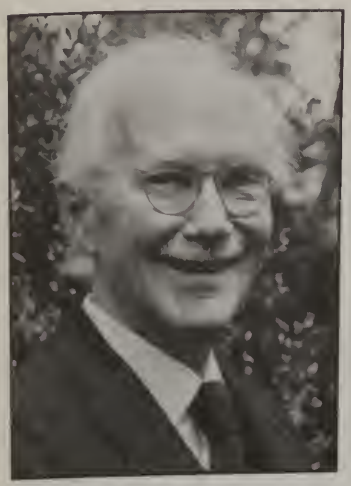
Walter Gilbert 1980 Chemistry

In the early 1950s, Dr. James Watson and Dr. Francis Crick described the shape of DNA, the chemical essence of the genes: nearly a decade later, the genetic code was broken. The next major hurdle would be finding a chemical process for identifying the sequence of the four nucleotides (DNA subunits, often referred to simply as A, C, G, and T) that make up the genetic alphabet.

Dr. Gilbert and Allan Maxam of Harvard worked out a chemical degradation method in which each of the four nucleotides in radioactively labeled pieces of DNA could be selectively destroyed, creating DNA fragments of varying lengths. These fragments could then be sorted by electrophoresis through a gel — like forcing them through a sieve with an electric field. The radioactive labels show the location of each fragment in the gel on x-ray film, and the identity of the last base on each fragment can then be read directly. Taking the order of all the fragments together gives the order of the several thousand nucleotides that make up a gene. Thousands of genes have been sequenced since the techniques of Dr. Gilbert and Dr. Frederick Sanger, a British Nobel Prize winner who developed a different technique for sequencing DNA, became widely available.

Dr. Gilbert was born in Boston in 1932. He graduated from Harvard College with an A.B. in chemistry and physics in 1953 and an A.M. from Harvard University in physics in 1954. In 1957, he received his Ph.D. in mathematics from Cambridge University, where he met Dr. James Watson, who eventually led him into molecular biology. Except for a brief period when he was chairman of Biogen N.V., a biotechnology company in Cambridge, Massachusetts, and Geneva, Switzerland, Dr. Gilbert has spent his entire career at Harvard, where he is now chairman of the Department of Cellular and Developmental Biology.

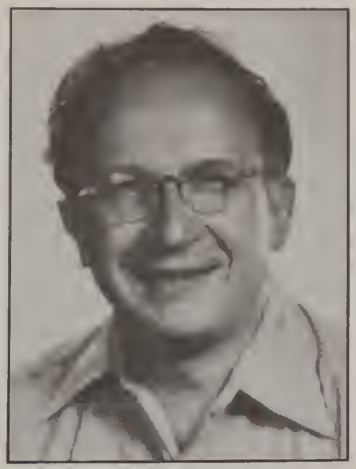
George D. Snell 1980 Physiology or Medicine



Dr. Snell is best known for his studies of the major histocompatibility complex or MHC, a group of closely linked genes, present in most and perhaps all vertebrates, that plays a major role in the regulation of immune processes. The complex was discovered independently in studies with mice by Drs. Snell and Peter Gorer, and was named histocompatibility-2, or H-2. It took several years of work, using the two different methodologies developed by the two investigators — and part of it in joint studies — before the great complexity of H-2 was even partly appreciated. The demonstration by Dr. Jean Dausset of a similar group of genes in humans, and by Dr. Baruj Benacerraf of an immunological role for H-2, first led to an appreciation of its importance. Numerous special strains of mice (congenic resistant strains) developed by Dr. Snell played a major role in much subsequent work.

Dr. Snell was born in Bradford, Massachusetts in 1903. He received his B.S. from Dartmouth College in 1926 and an Sc.D. from Harvard in 1930. After three years of teaching and two years as a postdoctoral fellow at the University of Texas, he moved to the Jackson Laboratory in Bar Harbor, Maine, where he remained until his retirement in 1973.

While at the University of Texas, Dr. Snell demonstrated for the first time that x-rays can produce hereditary changes in mammals (mice), and that the changes involve chromosome rearrangements rather than mutations of individual genes. Since his retirement, Dr. Snell has written, jointly with Drs. Dausset and Nathenson, a book on the MHC and related subjects, and has recently completed a book on ethics.



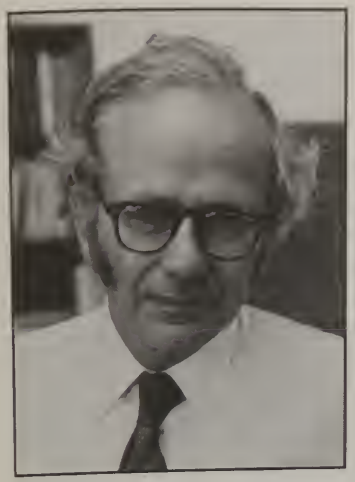
The action of hemoglobin, the oxygen-carrying red pigment found in red blood cells, depends on iron. The ability of chlorophyll to capture light and split water depends on magnesium. Other important molecules within the human body and throughout the living world depend on inorganic metals bound to organic chemicals.

"The inorganic fragment is not merely a weakly attached innocent bystander," Dr. Hoffmann said during his Nobel lecture on the relationship between metals and the hydrocarbon molecules of life. "It transforms essentially and strongly the bonding relationships in the molecule."

Dr. Hoffmann has spent his research career trying to bring order out of the chaos of these complex chemical relationships. Using what he calls "applied theoretical chemistry," he blends computations stimulated by experimentation with the construction of generalized models and frameworks to understand the geometry and reactivity of molecules, from organic and inorganic molecules to infinitely extended structures.

Born in Zloczow, Poland (now in the Soviet Union), in 1937, Dr. Hoffmann became an American citizen in 1955. He received his B.S. in chemistry from Columbia University in 1958. Harvard University awarded him an M.A. in 1960 and a Ph.D. in 1962. From 1962 to 1965, he stayed at Harvard as a Junior Fellow then moved to Cornell University, where he has remained since 1965. He is now the John A. Newman Professor of Physical Science at Cornell. A collection of his poetry, entitled ***"The Metamict State,"*** was published in 1987. In 1989, he will present an Annenberg/Public Broadcasting Corporation production called "The Chemical World," an introduction to chemistry in 26 half-hour shows.

David H. Hubel 1981 Physiology or Medicine



When the image of a scene falls on the retina, each of its 125 million receptors is influenced according to the amount of light falling on them. It is then up to the nerves in the retina and the brain to interpret these patterns of activity into form, color, movement, and depth. Working with cats and monkeys, Dr. Hubel and his colleague, fellow laureate Dr. Torsten N. Wiesel, have studied the way in which the visual information is processed in the early stages in the brain, especially in the primary visual cortex.

The work has also contributed to understanding binocular vision and the importance of early visual stimulation in development. It has led to practical applications in cataract surgery for infants and in surgery for strabismus, such as cross-eye.

Dr. Hubel was born in 1926 in Windsor, Canada. He was brought up in Montreal and educated at McGill University, from which he received his B.Sc. in 1947 and his M.D. in 1951. He came to the United States in 1954 and spent a year at Johns Hopkins University before entering the U.S. Army. He was assigned to work in the Neuropsychiatry Division of the Walter Reed Army Institute of Research, where he began his research career. He is now John Franklin Enders University Professor of Neurobiology at the Harvard Medical School.

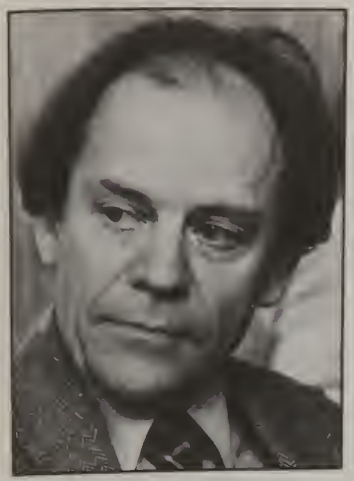
Roger W. Sperry 1981 Physiology or Medicine

Left brain, right brain. The two sides of the brain are linked through the corpus callosum — the brain's largest cable of nerve fibers. Reports that cutting the human callosum causes no detectable symptoms led Dr. Sperry to his "split-brain" research. He and his students showed that callosal cutting stops cross-integration of conscious experience, leaving left and right minds working in parallel. Analyses of the "split-brain" human faculties revealed the now-familiar left/right differences, and that the right brain is not retarded, as was previously thought, but has its own more spatial, less linear, form of intellect. This understanding changed theories of education and the conception of human consciousness.

Dr. Sperry's earlier work showed that brain networks for behavior can be preorganized in the growth process. A vast chemical prewiring scheme gives each neuron a chemical identity determining its selective outgrowths and connections. His findings disclosed the role in vertebrate development of specification at the cellular level and of individual cell-to-cell interactions. In doctoral research under Dr. Paul A. Weiss, Sperry showed by nerve/muscle transplantations that nerves are not functionally interchangeable and that the brain's wiring was not nearly as plastic as was formerly supposed. His mid-1960s mentalistic theory of consciousness has since become the dominant view in psychology. In later work he explored the wide-ranging implications of this "consciousness revolution" for science, philosophy, and social values.

Born in Hartford, Connecticut, in 1913, Dr. Sperry received an A.B. in English and an M.A. in psychology from Oberlin College, and a Ph.D. in zoology in 1941 from the University of Chicago. After posts at Harvard University, the Yerkes Laboratories, the University of Chicago, and the National Institutes of Health, he moved to the California Institute of Technology in 1954, where until 1984 he was Hixon Professor of Psychobiology and then Trustee's Professor Emeritus.

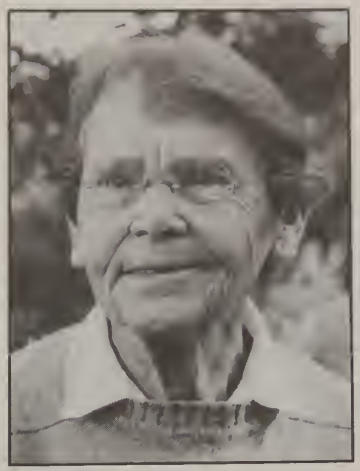
Torsten N. Wiesel 1981 Physiology or Medicine



For the retina lining the back of the eye to capture light and turn it into images the brain can understand, the neurons making up the retina must be organized into "ocular dominance columns." Working with his then-Harvard colleague Dr. David H. Hubel, Dr. Wiesel discovered that each neuron responds best to a particular stimulus and that for vision to work, all of the neurons must operate in concert, with each firing in a complicated arrangement. The neurons then transmit this visual information to the brain, where it can be interpreted. They had, according to the Nobel committee, discovered the essence of "information processing in the visual system."

Their work provides insights into the importance of early visual stimulation in proper development and problems relating to binocular vision.

Born in Uppsala, Sweden, in 1924, Dr. Wiesel later became a U.S. citizen. He received his M.D. from the Karolinska Institute in Stockholm in 1954. He came to 1954. He came to Johns Hopkins University in 1955, then moved to Harvard University in 1959. He remained at Harvard for 24 years, finally moving to Rockefeller University,where he is the Vincent and Brooke Astor Professor.



Gregor Mendel's principles of heredity had been rediscovered only 21 years before Dr. McClintock took Dr. C.B. Hutchinson's course, the only one open to the undergraduates of Cornell University. Although genetics as a discipline was not universally accepted by biologists of the time, she found it fascinating. In January 1922, after the course was over, Dr. Hutchinson called Dr. McClintock and invited her to take the only other genetics course — this one for graduate students — offered at Cornell. "Obviously, this telephone call cast the die for my future," Dr. McClintock wrote. "I remained in genetics thereafter."

Her early studies focused on the chromosomes of the maize plant, their components, and the relation of these to gene order and expression. That the genome was essentially stable was taken for granted at the time. In the mid-1940s, however, Dr. McClintock discovered the mobility of a class of genetic elements that was present in the maize genome. Such elements could transpose from one location to another, either within the same chromosome or to another chromosome. When inserted at a gene locus, the elements could take over control of of gene expression. Such elements have since been found in a number of organisms, both plant and animal, and their nature has been explored at the molecular level.

Born in Hartford, Connecticut, in June 1902, Dr. McClintock received all of her degrees from Cornell University in Ithaca, N.Y.: B.S. in 1923, M.S. in 1925, and Ph.D. in 1927. This was followed by several research fellowships and five years as an assistant professor at the University of Missouri. In 1942, she moved to the Department of Genetics of the Carnegie Institution of Washington at Cold Spring Harbor, New York (now the Cold Spring Harbor Laboratory), where she spent the rest of her career and where she resides today.

Henry Taube 1983 Chemistry

All chemical reactions fall into two categories. One is oxidation-reduction, in which electrons are transferred from one atom to the other. Such reactions are important because of the products that may be formed: for example the industrial production of sulfuric acid from sulfur, oxygen, and water or the electrolytic refining of copper. They are also important because of the energy they release: for example, the oxidation of sugar as it occurs in living cells. The transferring of electrons in a chemical reaction, however, is not a simple, straightforward process. Instead, it leads to rearrangements of atoms as the electrons move about.

Dr. Taube worked out the complicated electron interactions in metal complexes and determined that electrons move from one place to another by using a "chemical bridge." His discovery of these electron activities has had important implications for industry.

Born in Neudorf, Canada, in 1915, Dr. Taube received his B.S. and M.D. degrees from the University of Saskatchewan in 1935 and 1937, respectively, and his Ph.D. from the University of California at Berkeley in 1940. He taught at Berkeley for a year before moving to Cornell University in 1941, when he also became a naturalized American citizen. In 1946, he moved to the University of Chicago, where he served a term as chairman of the Chemistry Department. In 1962, Dr. Taube became a professor of chemistry at Stanford University, where he served as chairman of the department from 1972 to 1974 and from 1978 to 1979. He is still at Stanford.

R. Bruce Merrifield 1984 Chemistry

Proteins and the smaller peptides are both made from amino acids. The 20 different available amino acids determine the three-dimensional shape and biological properties of every protein.

Synthesizing peptides and proteins by hand for biological study was a laborious process. To make life easier for the protein researcher, Dr. Merrifield developed a technique called "solid-phase peptide synthesis," a rapid, automated method for assembling amino acids, one by one, into larger and larger chains. The first amino acid is anchored on an insoluble matrix of polystyrene (a common plastic) and then each additional amino acid is added in the desired order to make a complete protein. The method makes possible systematic studies of the biological activity of enzymes, hormones, and even antibodies. It also allows researchers to make sufficient quantities of proteins and peptides to study their three-dimensional structures and to determine how structure affects the proteins' action in the body.

This technique earned Dr. Merrifield the moniker "the Henry Ford of protein synthesis," since he used an assembly line approach to solve the difficult chemistry problems associated with in vitro peptide synthesis. This development is credited with aiding in the treatment and prevention of a number of diseases and genetic disorders and with stimulating progress in genetic engineering.

Born in Fort Worth, Texas, in 1921, he received his B.A. from the University of California at Los Angeles in 1943 and his Ph.D. in 1949. In 1944, Dr. Merrifield came to the then Rockefeller Institute for Medical Research; he became a professor at the Rockefeller University in 1966, where he continues his work today.

Michael S. Brown 1985 Physiology or Medicine

As the Nobel Assembly of the Karolinska Institute in Stockholm stated, Dr. Brown, with his collaborator, Dr. Joseph L. Goldstein, "revolutionized our knowledge about the regulation of cholesterol metabolism and the treatment of diseases caused by abnormally elevated cholesterol levels in the blood." For this, the two researchers received the Nobel Prize in Physiology or Medicine.

The discovery of LDL receptors —proteins on the surface of cells that capture cholesterol-carrying low-density lipoproteins (LDL) and pull them into the cell where they can be used — was the first step in a series of investigations by the two scientists. Their further studies, combining genetics and molecular biology, helped make it possible to use rationally designed drugs and diets to lower the amount of cholesterol in people whose high cholesterol levels increased their chances of heart disease.

Born in New York City in 1941, Dr. Brown received both his B.S. and M.D. at the University of Pennsylvania. He received his M.D. in 1966, then served for two years on the staff of the Massachusetts General Hospital in Boston, where he met Dr. Goldstein. They both later joined the National Institutes of Health, where Dr. Brown worked with Dr. Earl Stadtman in the Laboratory of Biochemistry. In 1971, Dr. Brown moved to the University of Texas Health Science Center in Dallas. In 1972, Dr. Goldstein joined the him and the two continued their collaboration there.

Dr. Joseph L. Goldstein 1985 Physiology or Medicine

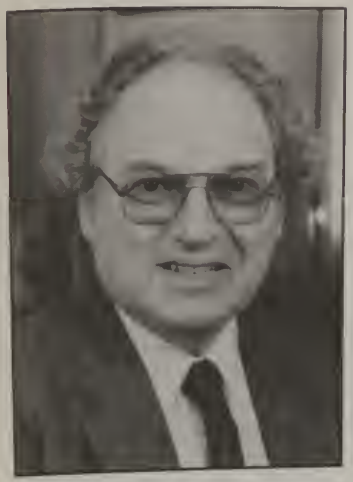
Finding the answers to two fundamental questions affecting heart disease — How does the body regulate the level of cholesterol in the blood? How might cholesterol metabolism be altered to lower the level of cholesterol in the blood? — earned Dr. Goldstein and Dr. Michael S. Brown, the Nobel Prize in Medicine or Physiology.

Cholesterol, a sticky molecule associated with a process that narrows the coronary arteries, is manufactured in the liver and is essential for cell membranes and the production of certain hormones. Because cholesterol cannot be dissolved in water, it must be carried through the blood as part of a special protein complex. Several types of protein-cholesterol complexes move the cholesterol to and from the liver. One critical form is called low-density lipoprotein (LDL), a high level of which has been shown to be associated with increased risk of heart disease. In 1973, Drs. Goldstein and Brown discovered that the surface membranes of certain cells carry molecules called receptors, proteins that bind LDL and remove it from the blood, thus lowering its concentration.

Their work provided a key insight into the natural metabolism of cholesterol in the body, and has already helped lead to new drugs that may help millions of individuals lower their cholesterol levels and thus their chances of a heart attack. As Dr. Goldstein once said, "Once one knows one has this receptor, one can begin to study the factors that turn it on and off, whether that is drugs or diet or any number of other things."

Born in Sumter, South Carolinia, in 1940, Dr. Goldstein received a B.S. from Washington and Lee University. In 1966 he received his M.D. from the University of Texas Health Science Center in Dallas, where the chairman of medicine offered him a future faculty position even before his graduation from medical school. He spent two years at the Massachusetts General Hospital as a house officer, and it was there that he met Dr. Brown, who has been his collaborator since they joined the Health Science Center faculty in the early 1970s.

Herbert A. Hauptman 1985 Chemistry



There had been arguments about how much information a beam of diffracted x-ray light could provide about a crystal's structure. The crystallographers of the 1950s felt the information was limited. Dr. Hauptman and his colleague, Dr. Jerome Karle, who were both then at the Naval Research Laboratory in Washington, D.C., believed differently.

They determined that the structure of a complicated crystal could be deduced from x-ray patterns using a fundamentally different analysis, called the "direct method." It was a mathematical formulation and a procedural approach that led to a quicker way to determine a crystal's shape, a breakthrough both in speed and accuracy. It allowed the team to determine the structures of molecules previously deemed too complicated for analysis. Within the next 12 years, many other molecular structures, such as reserpine, a drug used in the 1960s to treat high blood pressure and some nervous and mental disorders, were also solved.

Today, tens of thousands of structures have been determined with increased speed using their techniques. Thirty years ago, it took two years to work out the structure of a simple antibiotic molecule with only 15 atoms. Now, the structure of a 50-atom molecule can be determined in two days, and many others in the 100-200 atom range have been solved.

Although now widely hailed as a breakthrough with profound implications for work in many different scientific fields, their work was initially greeted with disbelief and criticism when first presented in 1954. It took nearly 15 years for crystallographers — who then could not understand the complex mathematical calculations — to accept the approach. Today, Hauptman and Karle are recognized as founders of a new era of research on molecular structure.

Dr. Hauptman, was born in New York City in 1917. He received a B.S. from the City College of New York in 1937. While working at the Naval Research Laboratory in 1955, he completed work for his Ph.D. at the University of Maryland.

Since 1970, Dr. Hauptman has been with the Medical Foundation of Buffalo, a small research center, that early on saw the potential of his work. From 1972 to 1988, he was research director of the foundation and, since 1986, he has been its president.

Jerome Karle 1985 Chemistry

In the world of biology and medicine, shape is everything. Genes determine the order of amino acid subunits in each protein, but it is the three-dimensional shape of the entire protein that makes it work. Identifying a molecule's shape is essential to understanding the relationship between its structure and its physical, chemical and biological properties.

Scientists had learned to make crystals of important molecules, blast them with x-rays, and then, by observing how the crystals scattered the x-rays, calculate the crystal's shape. The process was laborious, requiring years to determine the structure of even simple molecules with only a few atoms.

In the early 1950s, Dr. Karle, working in collaboration with his wife, Dr. Isabella Lugoski Karle (herself a physical chemist) and Dr. Herbert A. Hauptman, developed the "direct method" for determining the three-dimensional structure of crystalline materials. They created a series of mathematical formulas that allowed them to quickly interpret x-ray diffraction data to determine the structure of a number of biologically important molecules, including hormones, vitamins, and antibiotics — molecules vastly more complex than previous techniques could analyze.

There was only one problem. No one believed them. Fellow scientists failed to appreciate the implications of the mathematics used by Karle and his group, so there was some acrimony. In the preface to his Nobel lecture, Karle concludes with a thanks for the support from his wife "both technical and spiritual. . . . This was especially helpful during the early 1950s when a large number of fellow scientists did not believe a word we said." Within a decade, their techniques became the standard approach to crystallography.

Born in New York City in 1918, Dr. Karle received his B.S. in chemistry and biology in 1937 from the City College of New York and his M.S. from Harvard University in 1938. The University of Michigan awarded him both an M.S. and a Ph.D in physical chemistry in 1944, though the work had been completed a year earlier.

Before attending Michigan, he worked for the New York State Health Department in Albany where he devised the standard method for determining the amount of fluoride in drinking water. In 1943, he joined the University of Chicago's portion of the Manhattan Project. In 1946, Dr. Karle and his wife went to work at the Naval Research Laboratory in Washington, D.C., where he currently is the chief scientist of the Laboratory for the Structure of Matter.

Stanley Cohen 1986 Physiology or Medicine

It was another example of chance favoring the prepared mind. In the early 1950s Dr. Cohen joined Dr. Rita Levi-Montalcini's laboratory at Washington University in St. Louis as a young postdoctoral researcher. She had discovered the existence of a biologically active protein that stimulated nerve growth.

While conducting experiments in which salivary gland extracts, a source of the nerve growth factor, were injected into newborn mice, Dr. Cohen noticed that the mice opened their eyelids sooner than expected and grew teeth faster than normal. This observation, and dogged chemical analysis, led to the discovery of epidermal growth factor, a protein that stimulates the growth of epidermal cells, which make up the outer layers of the skin and other organs.

Although Dr. Cohen emphasizes the value of his work in understanding the fundamental growth activities of cells, it has also had important practical consequences for understanding how cells grow normally and how their abnormal growth causes diseases such as cancer and muscular dystrophy, and the delayed healing of wounds. Epidermal growth factor even has been used experimentally to produce skinlike sheets of cells used to treat burn victims.

Born in Brooklyn in 1922, Dr. Cohen received his undergraduate degree in both biology and chemistry from Brooklyn College, where he became interested in cell biology and embryonic development. He received his M.A. in zoology from Oberlin College in 1945 and his Ph.D. from the University of Michigan in 1948. He learned to use radioisotopes at Washington University in the early 1950s, where he met Dr. Arthur Kornberg, himself a Nobel Prize winner. He later joined co-laureate Dr. Levi-Montalcini in the Zoology Department.

In 1959, Dr. Cohen moved to Vanderbilt University to explore the chemistry and biology of epidermal growth factor. He remains at Vanderbilt, where, since 1976, he has been an American Cancer Society Research Professor and since 1986, distinguished professor.

Dudley R. Herschbach 1986 Chemistry

When two chemicals react with each other to produce some third substance, their atoms go through a series of complex reactions, forming and breaking chemical bonds, creating short-lived chemical intermediates, and finally arriving at an energetically stable configuration.

Chemists had speculated about the existence and the characteristics of these chemical intermediates, but it was difficult to perform experiments that would help shed light on the problem. Then Dr. Herschbach figured out a way to develop a new experimental approach.

Borrowing techniques from atomic physicists who had learned to study atoms by colliding them at extremely high speeds and then studying their subatomic fragments, Dr. Herschbach built a machine to squirt chemically pure beams of elementary chemicals — actually whole molecules — into a vacuum chamber. In the chamber the molecules smashed into each other, and creating chemical fragments that flew off in different directions. The fragments could be captured and analyzed to produce a picture of the chemical interactions. The initial reactions primarily involved alkali atoms and alkyl iodides.

Dr. Herschbach was born in San Jose, California, in June 1932. Of his years at nearby Campbell High School, he wrote: "I was at least as interested in football and other sports; perhaps that presaged my later pursuit of molecular collisions." In 1954, Dr. Herschbach received his B.S. in mathematics from Stanford University and his M.S. in chemistry a year later. He then moved to Harvard University, which awarded him an A.M. in physics in 1956 and a Ph.D. in chemical physics in 1958.

In 1959, Dr. Herschbach moved to the University of California at Berkeley to begin work on molecular beam devices. He returned to Harvard in 1963, where he became Frank B. Baird, Jr., Professor of Science in 1976. Dr. Herschbach also served as chairman of chemical physics, 1964-1977; chairman of chemistry, 1977-1980; and co-master of Currier House, 1981-1986. He lives in Lincoln, Massachusetts.

Yuan T. Lee 1986 Chemistry

The development of new instruments to understand how chemicals reacted with each other already was underway when Dr. Lee arrived at the University of California at Berkeley to begin his graduate studies in 1962. He quickly proved his instrument development skills while working on ion-molecule reactions during studies of molecular interactions.

With his Ph.D. in hand, Dr. Lee joined the lab of co-laureate Dr. Dudley Herschbach at Harvard University in February 1967 and helped build the first crossed molecular beam apparatus for non-alkali reactions.

"At first people thought he was just a brilliant experimentalist, the kind of guy who knew how to design and make the hardware that will do the experiment," said one colleague. "But it turned out Yuan Lee was just an ultramodest person . . . he also was a brilliant theoretician."

Born in November 1936 in Hsinchu, Taiwan, Dr. Lee started his education under the Japanese occupation of Taiwan. His elementary education was disrupted when Hsinchu's populace fled into the mountains to survive the bombings of World War II. He received his B.S. in chemistry from the National Taiwan University in 1959 and his M.S. from the National Tsinghua University. He received his Ph.D. from the University of California at Berkeley in 1965.

After his work in Dr. Herschbach's lab, Lee moved to the University of Chicago in October 1968 to construct a new generation of crossed molecular beam apparatus. In 1974, he returned to the University of California at Berkeley as a professor of chemistry and a principal investigator at the Lawrence Berkeley Laboratory, where his lab now runs more than half a dozen molecular beam devices. He became an American citizen the same year.

Rita Levi-Montalcini 1986 Physiology or Medicine

The research began with a chance experiment: mouse sarcoma tissue transplanted into a three-day old chick embryo caused nearby nerve fibers to grow explosively.

But the tumor cells produced too little of the unknown factor to identify, so Dr. Levi-Montalcini traveled to Rio de Janerio, where a friend had built an efficient tissue culture system. There, she devised a technique that allowed her to explore the effect of mouse sarcoma factor in virtro on sensory and sympathetic ganglia of the chick embryo. working in the Department of Zoology at Washington University in St. Louis with biochemist and co-laureate Dr. Stanly Cohen, she explored this factor's effect on its target cells. Then luck intervened again. The team used snake venom as part of the preparation, expecting it to stop nerve growth. Instead, it proved to be a potent source of nerve growth stimulation. Their subsequent discovery that mouse submandicular salivary glands are an even more potent source of the molecule, known since 1964 as the nerve growth factor (NGF) marked the beginning of the extensive studies she has pursued ever since to identify the chemical nature of NGF and explore its spectrum and mechanism of action.

The discovery of NGF created a whole new field of research that led to the discovery of a number of growth factors including epidermal growth factor, found by Dr. Cohen. Research in the late 1970s linked the discovery of oncogenes, genes that can convert normal cells into cancerous cells, to some growth factors.

Dr. Levi-Montalcini was born in Turin, Italy, in 1909, and later became a dual U.S. and Italian citizen. She graduated from medical school in Turin in 1936 with a degree in medicine and surgery. The politics of anti-Semitism during World War II blocked her from performing research or working as a physician, and she ended up installing a small research lab in her bedroom. She returned to the University of Turin in 1945 where she stayed, until moving to Washington University in 1956 for what was supposed to be a brief visit as a guest researcher. She stayed in St. Louis until 1977, when she retired as a full professor. From 1969 to 1978, she commuted between St. Louis and the Institute of Cell Biology of the Italian National Council of Research in Rome, which she directed during that time. Since retiring in 1979 she has been a guest professor at the institute.

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